

WHAT IS CLAIMED IS:

1. A method of reproducing gray levels to represent the density of each pixel of an output image by binary or multivalued data based on a one-to-one correspondence of each pixel of an input image to each element of a threshold matrix (a mask), comprising the steps of:

providing non-blue noise properties for each respective gray level of a dot pattern generated in a pixel block of a standard size using the mask of a size corresponding to a size smaller or substantially smaller than the standard size of the pixel block; and

generating, in the output image, no visually unpleasing artifacts, when the input image undergoes the gray level reproducing process and the produced image is output by an output device.

2. The method according to claim 1, wherein said output device has a resolution of about 600 dpi or greater.

3. The method according to claim 1, wherein said artifacts include moiré and/or a certain repetitive pattern both having visually unpleasing contrast.

4. The method according to claim 1, wherein said dot pattern generated by the mask has a value equal to or greater than 0.6 dB as an average value of anisotropy at each respective gray

level.

5. The method according to claim 1, wherein adjacent masks are shifted along boundaries when said mask is repeatedly used and arranged two-dimensionally.

5 6. The method according to claim 1, wherein said mask is not a quadrilateral.

7. The method according to claim 1, wherein, as a process of determining a dot distribution at each respective gray level for producing said mask, a repulsive potential is assigned to
10 all dots constructing a determined dot pattern of a specific gray level and a new dot to determine a dot distribution for a next gray level is placed at a position having the lowest repulsive potential in/within the sum of said repulsive potentials .

15 8. A method of reproducing gray levels of a color image using the method according to any one of claims 1 to 7, wherein the color image is separated into a plurality of color components; and at least one of the color components of the color image is used as the input image.

20 9. A method of reproducing gray levels to represent the density of each pixel of an output image by binary or multivalued data based on a one-to-one correspondence of each pixel of an input image to each element of a threshold matrix (a mask), comprising the steps of:

providing non-blue noise properties for each respective gray level of a dot pattern generated by the single mask; and

generating, in the output image, no visually unpleasing artifacts when the input image undergoes the gray level reproducing process and the produced image is output by an output device.

10. The method according to claim 9, wherein said output device has a resolution of about 600 dpi or greater.

11. The method according to claim 9, wherein said artifacts include moiré and/or a certain repetitive pattern both having visually unpleasing contrast.

12. The method according to claim 9, wherein adjacent masks are shifted along boundaries when said mask is repeatedly used and arranged two-dimensionally.

13. The method according to claim 9, wherein said mask is not a quadrilateral.

14. The method according to claim 9, wherein, as a process of determining a dot distribution at each respective gray level for producing said mask, a repulsive potential is assigned to all dots constructing a determined dot pattern of a specific gray level and a new dot to determine a dot distribution for a next gray level is placed at a position having the lowest repulsive potential in/within the sum of said repulsive potentials.

15. A method of reproducing gray levels of a color image using the method according to any one of claims 9 to 14, wherein the color image is separated into a plurality of color components; and at least one of the color components of the color image is used as the input image.

16. A method of reproducing gray levels to represent the density of each pixel of an output image by binary or multivalued data based on a one-to-one correspondence of each pixel of an input image to each element of a threshold matrix (a mask), comprising the steps of:

providing a plurality of isolated spectra for a two-dimensional spatial frequency spectrum of an individual dot pattern generated by a single mask at each respective gray level; and

generating, in the output image, no visually displeasing artifacts when the input image undergoes the gray level reproducing process and the produced image is outputted by an output device.

17. The method according to claim 16, wherein each dot pattern generated by said mask has a noise component having small low frequency components of a one-dimensional power spectrum due to weak irregularity (perturbation) or pseudo-periodicity introduced at a plurality of gray levels.

18. The method according to claim 16, wherein said output

device has a resolution of about 600 dpi or greater.

19. The method according to claim 16, wherein said artifacts include moiré and/or a certain repetitive pattern both having visually unpleasing contrast.

5 20. The method according to claim 16, wherein adjacent masks are shifted along boundaries when said mask is repeatedly used and arranged two-dimensionally.

21. The method according to claim 16, wherein said mask is not a quadrilateral.

10 22. The method according to claim 16, wherein, as a process of determining a dot distribution at each respective gray level for producing said mask, a repulsive potential is assigned to all dots constructing a determined dot pattern of a specific gray level and a new dot to determine a dot distribution for
15 a next gray level is placed at a position having the lowest repulsive potential in/within the sum of said repulsive potentials.

23. A method of reproducing gray levels of a color image using the method according to any one of claims 16 to 22, wherein the
20 color image is separated into a plurality of color components; and at least one of the color components of the color image is used as the input image.

24. A method of representing the density of each pixel of an output image by binary or multivalued data based on a one-to-one

correspondence of each pixel of an input image to each element of a threshold matrix (a mask), comprising the steps of:

said mask having the size of an array of a plurality of element masks, each of which being of the same size as that of

5 a mask used in the dispersed-dot dithering method; and

a dot pattern generated by said mask:

(1) having at least a set of element pixel blocks, each of which corresponding to each element mask and having the same dot distribution at each respective gray level;

10 (2) having weak irregularity (perturbation) or pseudo-periodicity introduced at a certain gray level;

(3) having an equal number of dots in every element pixel block at each respective gray level; and

15 (4) having an equal number of dots in four individual partial element pixel blocks each having a quarter size of an element pixel block at each respective (4n)th (n indicates a positive integer) gray level.

25. The method according to claim 24, wherein said weak irregularity (perturbation) or pseudo-periodicity is
20 introduced at a certain low gray level equal to or higher than the first gray level.

26. The method according to claim 24, wherein the size of said mask is smaller or substantially smaller than the size corresponding to a standard size pixel block and the mask is

repeatedly arranged two-dimensionally and regularly corresponding to the entire input image.

27. The method according to claim 24, wherein said mask has the size of an array of a plurality of element masks, each of which being of the same size as that of a mask used in the dispersed-dot dithering method.

28. The method according to claim 24, wherein said dot pattern generated in the output image has no visually unpleasing artifacts, when the input image undergoes said gray level reproducing process and the produced image is outputted by an output device.

29. The method according to claim 28, wherein said output device has a resolution of about 600 dpi or greater.

30. The method according to claim 28, wherein said artifacts include moiré and/or a certain repetitive pattern both having visually unpleasing contrast.

31. The method according to claim 24, wherein adjacent masks are shifted along boundaries when said mask is repeatedly used and arranged two-dimensionally.

32. The method according to claim 24, wherein said mask is not a quadrilateral.

33. The method according to claim 24, wherein said weak irregularity (perturbation) or pseudo-periodicity is implemented by providing small pixel blocks, each having a

number of pixels equal to or smaller than a quarter ($1/4$) of the total number of pixels in an element pixel block, at predetermined positions in all or a part of the individual element pixel blocks, each corresponding to each element mask, and by selecting one pixel for a dot in each of said small pixel blocks.

34. The method according to claim 24, wherein, as a process of determining a dot distribution at each respective gray level for producing said mask, a repulsive potential is assigned to all dots constructing a determined dot pattern of a specific gray level and a new dot to determine a dot distribution for a next gray level is placed at a position having the lowest repulsive potential in/within the sum of said repulsive potentials.

35. A method of reproducing gray levels of a color image using the method according to any one of claims 24 to 34, wherein the color image is separated into a plurality of color components; and at least one of the color components of the color image is used as the input image.

36. An apparatus for reproducing gray levels to represent the density of each pixel of an output image by binary or multivalued data based on a one-to-one correspondence of each pixel of an input image to each element of a threshold matrix (a mask), wherein:

providing non-blue noise properties for each respective gray level of a dot pattern generated in a pixel block of a standard size using the mask of a size smaller or substantially smaller than the standard size of the pixel block; and

5 generating, in the output image, no visually unpleasing artifacts, when the input image undergoes the gray level reproducing process and the image is output by an output device.

37. An apparatus for reproducing gray levels to represent the density of each pixel of an output image by binary or multivalued data based on a one-to-one correspondence of each pixel of an input image to each element of a threshold matrix (a mask), wherein:

providing non-blue noise properties for each respective gray level of a dot pattern generated by the single mask; and

15 generating, in the output image, no visually unpleasing artifacts when an input image undergoes a gray level reproducing process and the produced image is output by an output device.

38. An apparatus for reproducing gray levels to represent the density of each pixel of an output image by binary or multivalued data based on a one-to-one correspondence of each pixel of an input image to each element of a threshold matrix (a mask), wherein:

providing a plurality of isolated spectra for a two-dimensional spatial frequency spectrum of a dot pattern

generated by the single mask at each respective gray level; and
generating, in an output image, no visually unpleasing artifacts when the input image has undergone a gray level reproducing process and output by an output device.

5 39. An apparatus for representing the density of each pixel of an output image by binary or multivalued data based on a one-to-one correspondence of each pixel of an input image to each element of a threshold matrix (a mask), wherein:

10 composing said mask by an array of a plurality of element masks, each of which being of the same size as that of a mask used in the dispersed-dot dithering method; and

generating, by said mask, a dot pattern:

15 (1) having at least a set of element pixel blocks, each of which corresponding to each element mask and having the same dot distribution at each respective gray level;

(2) having weak irregularity (perturbation) or pseudo-periodicity introduced at a certain gray level;

(3) having an equal number of dots in every element pixel block at each respective gray level; and

20 (4) having an equal number of dots in four individual partial element pixel blocks each having a quarter size of an element pixel block at each respective $(4n)$ th (n indicates a positive integer) gray level.

40. The apparatus according to claim 39, wherein said weak

irregularity (perturbation) or pseudo-periodicity is introduced at a certain low gray level equal to or higher than the first gray level.

41. The apparatus according to claim 39, wherein the size of said mask is smaller or substantially smaller than the size corresponding to a standard size of a pixel block and repeatedly arranged two-dimensionally and regularly corresponding to the entire input image.

42. An apparatus for reproducing gray levels to represent the density of each pixel of an output image by binary or multivalued data based on a one-to-one correspondence of each pixel of an input image to each element of a threshold matrix (a mask), comprising:

storage means for storing the threshold matrix;

comparison means for comparing each value of the threshold matrix with density of each pixel of the input image; and

output means for outputting a binary or multivalued dot pattern based on comparison results of said comparison means,

wherein:

said threshold matrix has a size corresponding to a size smaller or substantially smaller than a standard size pixel block, a dot pattern generated in the standard size pixel block has non-blue noise properties at each respective gray level,

and visually displeasing artifacts are not generated in the output image when the input image undergoes the gray level reproducing process and the produced image is output by an output device.

5 43. The apparatus according to claim 42, wherein said output device has a resolution of about 600 dpi or greater.

44. The apparatus according to claim 42, wherein said artifacts include moiré and/or a certain repetitive pattern both having visually displeasing contrast.

10 45. An apparatus for reproducing gray levels to represent the density of each pixel of an output image by binary or multivalued data based on a one-to-one correspondence of each pixel of an input image to each element of a threshold matrix (a mask), comprising:

15 storage means for storing the threshold matrix;

comparison means for comparing each value of the threshold matrix with density of each pixel of the input image; and

20 output means for outputting a binary or multivalued dot pattern based on comparison results of said comparison means, wherein:

said threshold matrix produces, by itself, the dot pattern having non-blue noise properties at each respective gray level, and generates, in the output image, no visually

unpleasing artifacts when the input image undergoes the gray level reproducing process and the produced image is output by an output device.

46. The apparatus according to claim 45, wherein said output
5 device has a resolution of about 600 dpi or greater.

47. The apparatus according to claim 45, wherein said artifacts include moiré and/or a certain repetitive pattern both having visually unpleasing contrast.

48. An apparatus for reproducing gray levels to represent the
10 density of each pixel of an output image by binary or multivalued data based on a one-to-one correspondence of each pixel of an input image to each element of a threshold matrix (a mask), comprising:

storage means for storing the threshold matrix;

15 comparison means for comparing each value of the threshold matrix with density of each pixel of the input image; and

output means for outputting a binary or multivalued dot pattern based on comparison results of said comparison means,

20 wherein:

said threshold matrix produces, by itself, a dot pattern having a plurality of isolated spectra in a two-dimensional spatial frequency spectrum at each respective gray level and assigns a noise component having small low frequency components

to a one-dimensional power spectrum of a dot distribution at a plurality of gray levels.

49. The apparatus according to claim 48, wherein said threshold matrix assigns said noise component by introducing
5 weak irregularity (perturbation) or pseudo-periodicity in the dot distribution at said plurality of gray levels.

50. An apparatus for reproducing gray levels to represent the density of each pixel of an output image by binary or multivalued data based on a one-to-one correspondence of each pixel of an
10 input image to each element of a threshold matrix (a mask), comprising:

storage means for storing the threshold matrix;

comparison means for comparing each value of the threshold matrix with the density of each pixel of the input
15 image; and

output means for outputting a binary or multivalued dot pattern based on comparison results of said comparison means, wherein:

said mask has the size of an array of a plurality of element
20 masks, each of which being of the same size as that of a mask used in the dispersed-dot dithering method, and generates a dot pattern:

(1) having at least a set of element pixel blocks, each of which corresponding to each element mask and having the same

dot distribution at each respective gray level;

(2) having weak irregularity (perturbation) or pseudo-periodicity introduced at a certain gray level;

(3) having an equal number of dots in every element pixel
5 block at each respective gray level; and

(4) having an equal number of dots in four individual
partial element pixel blocks each having a quarter size of an
element pixel block at each respective (4n)th (n indicates a
positive integer) gray level.

10 51. The apparatus according to claim 50, wherein said weak
irregularity (perturbation) or pseudo-periodicity is
introduced at a certain low gray level equal to or higher than
the first gray level.

52. A threshold matrix (a mask) for use in converting the
15 density of each pixel of an input image into binary or multivalued
data, wherein said threshold matrix has a size corresponding
to a size smaller or substantially smaller than a standard size
of a pixel block, a dot pattern generated by said threshold
matrix in the standard size pixel block has non-blue noise
20 properties at each respective gray level, and visually
unpleasing artifacts are not generated in an output image when
the input image undergoes the gray level reproducing process
and the produced image is output by an output device.

53. The threshold matrix according to claim 52, wherein said

output device has a resolution of about 600 dpi or greater.

54. The threshold matrix according to claim 52, wherein said artifacts include moiré and/or a certain repetitive pattern both having visually unpleasing contrast.

5 55. A threshold matrix (a mask) for use in converting the density of each pixel of an input image into binary or multivalued data, wherein said threshold matrix produces, by itself, a dot pattern having non-blue noise properties at each respective gray level, and generates in an output image no visually
10 unpleasing artifacts when the input image undergoes the gray level reproducing process and the produced image is output by an output device.

56. The threshold matrix according to claim 55, wherein said output device has a resolution of about 600 dpi or greater.

15 57. The threshold matrix according to claim 55, wherein said artifacts include moiré and/or a certain repetitive pattern both having visually unpleasing contrast.

58. A threshold matrix (a mask) for use in converting the density of each pixel of an input image into binary or multivalued data, wherein said threshold matrix produces, by itself, a dot
20 pattern having a plurality of isolated spectra in a two-dimensional spatial frequency spectrum at each respective gray level and assigns a noise component having small low frequency components to a one-dimensional power spectrum of the dot

distribution at a plurality of gray levels.

59. The threshold matrix according to claim 58, wherein said threshold matrix assigns said noise component by introducing weak irregularity (perturbation) or pseudo-periodicity in the
5 dot distribution at said plurality of gray levels.

60. A threshold matrix (a mask) for use in converting the density of each pixel of an input image into binary or multivalued data, wherein said mask having the size of an array of a plurality of element masks, each of which being of the same size as that
10 of a mask used in the dispersed-dot dithering method, and a generated dot pattern has:

(1) at least a set of element pixel blocks, each of which corresponding to each element mask and having the same dot distribution at each respective gray level;

15 (2) weak irregularity (perturbation) or pseudo-periodicity introduced at a certain gray level;

(3) an equal number of dots in every element pixel block at each respective gray level; and

20 (4) an equal number of dots in four individual partial element pixel blocks each having a quarter size of an element pixel block at each respective $(4n)$ th (n indicates a positive integer) gray level.

61. The threshold matrix according to claim 60, wherein said weak irregularity (perturbation) or pseudo-periodicity is

introduced at a certain low gray level equal to or higher than the first gray level.

62. A computer-readable storage medium storing a control program for controlling a gray level reproducing process to
5 represent the density of each pixel of an output image by binary or multivalued data based on a one-to-one correspondence of each pixel of an input image to each element of a threshold matrix (a mask), comprising:

10 a threshold matrix having a size corresponding to a size smaller or substantially smaller than a standard size of a pixel block, a dot pattern generated, by the threshold matrix, in a pixel block of the standard size having non-blue noise properties at each respective gray level, wherein visually displeasing artifacts are not generated in the output image when
15 the input image undergoes the gray level reproducing process and the produced image is output by an output device; and

a module for comparing each value of the threshold matrix with the density of each pixel of the input image, and for controlling an output of each binary or multivalued dot pattern
20 depending on the comparison results.

63. The computer-readable storage medium according to claim 62, wherein said output device has a resolution of about 600 dpi or greater.

64. The computer-readable storage medium according to claim

62, wherein said artifacts include moiré and/or a certain repetitive pattern both having visually unpleasing contrast.

65. A computer-readable storage medium storing a control program for controlling a gray level reproducing process to
5 represent density of each pixel of an output image by binary or multivalued data based on a one-to-one correspondence of each pixel of an input image to each element of a threshold matrix (a mask), comprising:

a threshold matrix for producing , by itself, a dot
10 pattern having non-blue noise properties at each respective gray level, wherein visually unpleasing artifacts are not generated when the input image undergoes the gray level reproducing process and the produced image is outputted by an output device; and

15 a module for comparing each value of the threshold matrix with the density of each pixel of the input image, and for controlling an output of each binary or multivalued dot pattern depending on the comparison results.

66. The computer-readable storage medium according to claim
20 65, wherein said output device has a resolution of about 600 dpi or greater.

67. The computer-readable storage medium according to claim 65, wherein said artifacts include moiré and/or a certain repetitive pattern both having visually unpleasing contrast.

68. A computer-readable storage medium storing a control program for controlling a gray level reproducing process to represent the density of each pixel of an output image by binary or multivalued data based on a one-to-one correspondence of each pixel of an input image to each element of a threshold matrix (a mask), comprising:

the threshold matrix producing, by itself, a dot pattern having a plurality of isolated spectra in a two-dimensional spatial frequency spectrum at each respective gray level and assigning a noise component having small low frequency components to a one-dimensional power spectrum of a dot distribution at each of a plurality of gray levels; and

a module for comparing each value of the threshold matrix with the density of each pixel of the input image, and for controlling an output of each binary or multivalued dot pattern depending on the comparison results.

69. The computer-readable storage medium according to claim 68, wherein said noise component is caused by introducing weak irregularity (perturbation) or pseudo-periodicity in the dot distribution at said plurality of gray levels.

70. A computer-readable storage medium storing a control program for controlling a gray level reproducing process to reproduce the density of each pixel of an output image by binary or multivalued data based on a one-to-one correspondence of each

pixel of an input image to each element of a threshold matrix (a mask), comprising:

the threshold matrix having the size of an array of a plurality of element masks, each of which being of the same size
5 as that of a mask used in the dispersed-dot dithering method, wherein a generated dot pattern has:

(1) at least a set of element pixel blocks each of which corresponding to each element mask and having the same dot distribution at each respective gray level;

10 (2) weak irregularity (perturbation) or pseudo-periodicity introduced at a certain gray level;

(3) an equal number of dots in every element pixel block at each respective gray level; and

15 (4) an equal number of dots in four individual partial element pixel blocks each having a quarter size of each element pixel block at each respective $(4n)$ th (n indicates a positive integer) gray level; and

20 a module for comparing each value of the threshold matrix with density of each pixel of the input image, and for controlling an output of each binary or multivalued dot pattern depending on the comparison results.

71. The computer-readable storage medium according to claim 70, wherein said weak irregularity (perturbation) or pseudo-periodicity is introduced at a certain low gray level

equal to or higher than the first gray level.

72. A gray level reproducing apparatus for associating each pixel of an input image with each element of a threshold matrix (a mask) based on a one-to-one correspondence to reproduce the density of each pixel of an output image using binary or multivalued data, wherein:

10 a dot pattern generated by the threshold matrix has an anisotropy spectrum having an average value of 3 dB or more and a maximum value of 10 dB or more at each respective gray level, and visually unpleasing artifacts are not generated in the output image when the input image undergoes the gray level reproducing process and the produced image is outputted by an output device.

73. The computer-readable storage medium according to claim 15 72, wherein said output device has a resolution of about 600 dpi or greater.

74. The apparatus according to claim 72, wherein said artifacts include moiré and/or a certain repetitive pattern both having visually unpleasing contrast.